Journal of Fundamental and Applied Sciences

Research Article

ISSN 1112-9867

Available online at http://www.jfas.info

ENERGY EFFICIENCY OF A PHOTOVOLTAIC CELL BASED THIN FILMS CZTS BY SCAPS

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Received: 30 December 2015 / Accepted: 12 April 2016 / Published online: 01 May 2016

ABSTRACT

In the overall context of the diversification of the use of natural resources, the use of renewable energy including solar photovoltaic has become increasingly indispensable. As such, the development of a new generation of photovoltaic cells based on CuZnSnS4 (CZTS) looks promising. Cu2ZnSnS4 (CZTS) is a new film absorber, with good physical properties (band gap energy 1.4-1.6 eV [01] with a large absorption coefficient over 10^4 cm^{-1}). Indeed, the performance of these cells exceeded 30% in recent years.In the present paper, our work based on modeling and numerical simulation, we used SCAPS to study the performance of solar cells based on Cu2ZnSnS4 (CZTS) and thus evaluate the electrical efficiency η for typical structures of ZnO / i- ZnO / CdS / CZTS and ITO / ZnO / CdS / CZTS. Furthermore, the influence of the change of CdS by ZnSe buffer layer was treated in this paper.

Key words*:* solar cell; photovoltaic; thin film Cu2ZnSnS4; simulation; SCAPS.

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doi: http://dx.doi.org/10.4314/jfas.v8i2.13

1. INTRODUCTION

Energy production is a challenge of great importance for the coming years. Indeed, the energy needs of industrialized societies are increasing. Today, a large part of global energy production comes from fossil sources.

In contrast to the fossil energy, renewable energies are unlimited energy resource grouping a

number of technological fields valued according to energy source and useful energy obtained. One of the most important sectors is the photovoltaic solar energy which are interested in this present work. Many research teams are exploring and developing thin film materials to make solar cells at lower cost and more efficient.

In this perspective, the sector-based compounds CuInSe2 and recently Cu2ZnSnS4 (CZTS) is emerging as it presents itself as an attractive alternative.

CZTS is a semi-conductor material of choice, since it is made of current and non-toxic components, it CZTS has optical and electronic properties similar to that in CIGS. Seol et al, preparded CZTS thin film by RF magnetron sputtering[01]**.** Tanaka et al, prepared CZTS thin film films by co-evaporation of elemental sources [02]**.** katagiri et al, reported the preparation of CZTS thin films by RFsources co-sputtering followed by vapor phase sulfurization or by sulphyrizing electron-beam-evaporrated precursors[03-11].V.G Rajeshmon et al ,have reported an efficiency of 1.85 %[12].The objective of this work is to study the influence of buffer layers and layers windows in the four typical structures (ZnO / i- ZnO / (CdS.ZnSe.)/ CZTS and ITO / ZnO / (CdS.ZnSe.)/CZTS)on the electrical characteristics of a solar cell based CZTS.

Using SCAPS 1D software to simulate the physical characteristics (current density Jsc short circuit, open circuit voltage VCO, form factor FF and the conversion efficiency of the solar cell studied (η).

2. SOLAR CELL BASED ON CZTS

2.1.Composition and manufacturing CZTS cells

From top to bottom, a CZTS cell is composed:

- A protective glass.
- A transparent conductive layer of intrinsic zinc oxide i-ZnO or a layer of ITO (it is sometimes preceded by a ZnO layer doped with aluminum, 400 nm thick).
- A layer of cadmium sulfide (CdS) or zinc selenium layer (ZnSe).
- The CZTS layer (thickness of about 1.5 microns).
- The lower conductor, usually molybdenum (thickness of 300 nm).
- The substrat.

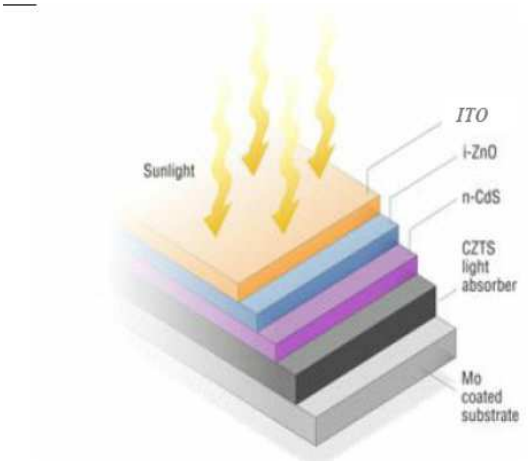


Fig.1. Structure of a photovoltaic cell CZTS

Cell structures used in this simulation is the (ZnO/i- ZnO/CdS/CZTS and ITO / ZnO / CdS / CZTS) as shown in Figure 02, the cell structures are made of two windows layers, the first structure was used a layer of highly conductive n-type (Al-ZnO) doped (ZnO-n) and an intrinsic ZnO layer (i-ZnO).

In the second structure was used an n-type layer highly conductive Al-doped ZnO (ZnO-n) and an ITO layer.

The default function of temperature is set to 300K.

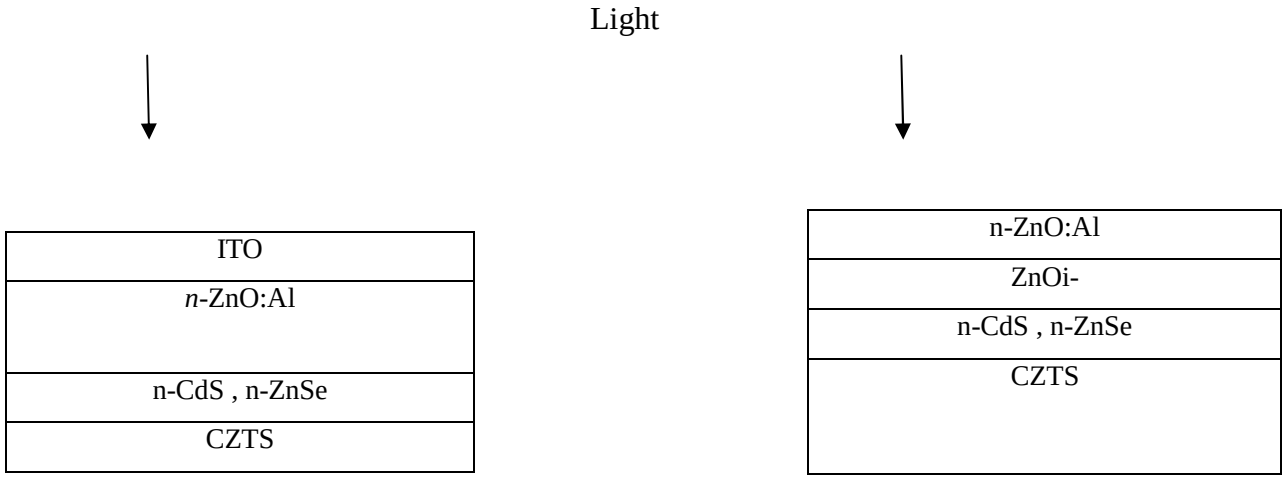


Fig.2. Structure of Solar cell

2.2. Methodology

SCAPS is Windows application software. It was developed to simulate the electrical

characteristics of heterojunction solar cells and thin film. It has been extensively tested in solar cells based on CdTe and Cu (In, Ga) Se2 by M.Burgelman et al.

The simulated and measured results were in good agreement [13-14].

We used in LPDS laboratory for the first time on With SCAPS, it is possible to simulate structures consisting of a defined number of layers (up to 7 intermediate layers as well as the front and rear contacts), with different doping profiles and energy distributions of donors or acceptors levels given in volume and interfaces for an arbitrary spectrum of light. In principle, any digital program capable of solving the semiconductor basic equations can be used to model the thin film solar cells. Among these simulation programs, mention: PC-1D which was developed in 1985 (first version) and 1988 second version [15], ADEPTF [16] and AMPS [17].

The basic equations are as follows: Poisson's equation that relates the load to the electrostatic potential and continuity equations for electrons and holes. However, several additional options must be present in the program when you want to simulate thin film solar cells. It should be able to take into account the presence of several layers in the cell and the recombination event at the interface of the layers introduced by the discontinuities in the energy band (Ec and Ev).

Similarly, the software should properly address the recombination problem and the generation-recombination centers in the deep states in the volume of the layers, it should also be able to calculate and simulate electro-optical measurements typically performed on solar cells thin layers, not only the characteristic I (V), but also the spectral response and capacitance measurements C (V) and C (f). We also seek to achieve convergence at least for the most common cell structures in thin layers.

2.3. The physical parameters used in the simulation

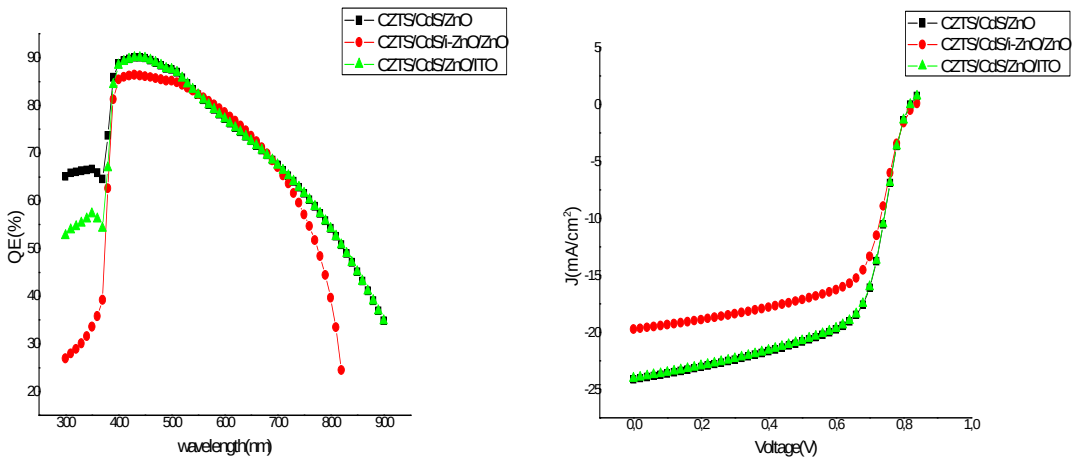
The basic values for the physical parameters used in the study are cited from experimental studies which are summarized in the following Table01:

Table 1. Physics parameters

Parameters	*p*-CZTS	*n*-In2S3	n-CdS	n-ZnSe	*i*-ZnO	*n*-ZnO:Al	n-ITO
Thickness, W (nm)	2500	50	50	80	50	200	10
Relative permittivity	10	13.5	10	10	9	9	10
Electron affinity (eV)	4.5	4.7	4.5	4.090	4.6	4.6	4.1
***Eg* (eV)**	1.5	2.8	2.4	2.9	3.3	3.3	3.6
***Nc* (cm-3)**	$2.2*10^{18}$	1.810^{18}	$1.5*10^{18}$	$1.5*10^{18}$	$2.2*10^{18}$	$2.2*10^{18}$	$2*10^{18}$
***Nv* (cm-3)**	$1.8*10^{19}$	$4*10^{13}$	$1.8*10^{18}$	$1.8*10^{19}$	$1.8*10^{19}$	$1.8*10^{19}$	$1.8*10^{19}$
Electron mobility (cm2_$V^{-1}s^{-1}$)	100	400	25	25	25	25	50
Hole mobility (cm2_$V^{-1}s^{-1}$)	25	210	100	100	100	100	75
Donor concentration (cm^{-3})	0	$1*10^{17}$	$1*10^{17}$	$1*10^{17}$	$1*10^{5}$	$1*10^{17}$	$1*10^{19}$
Acceptor concentration (cm^{-3})	$1*10^{16}$	0	0	0	0	0	0

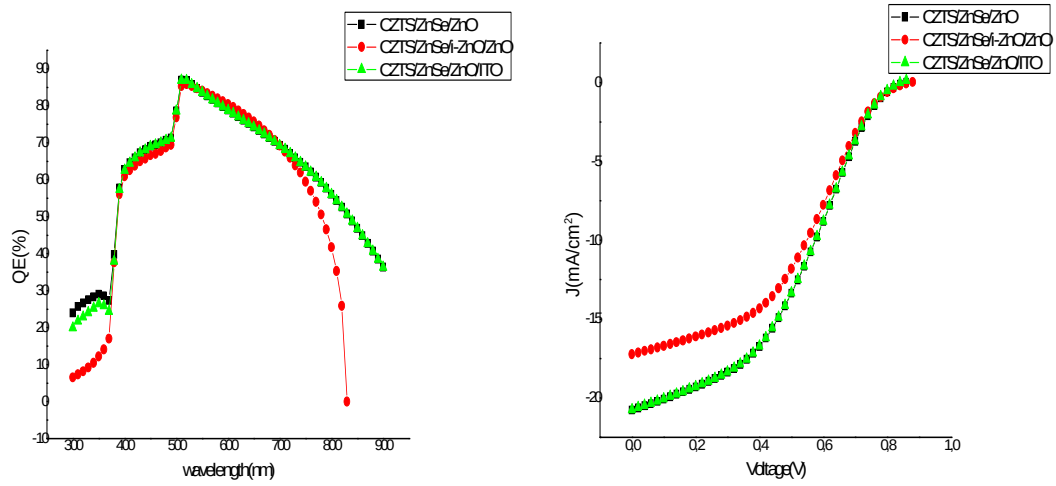
3. RESULTS AND DISCUSSION

In order to optimize a specific design of the two structures hetero-junction ZnO / i- ZnO / CdS / CZTS and ITO / ZnO / CdS / CZTS, we must analyze and interpret the results to determine the influence of physical and technological parameters on the device performance. In this work, we have determined the short-circuit current density (Jsc), the open circuit voltage (Voc), the fill factor (FF) and photovoltaic conversion efficiency (η). The results obtained in this step are presented in the following section.



(a) (b)

Fig.3. a) Characteristic I-V of the first configuration of the CZTS cell, b) the spectral response with the CdS buffer layer



(a) (b)

Fig.4. a) Characteristic I-V of the first configuration of the CZTS cell, b) the spectral response with the ZnSe buffer layer

We note that these characteristics IV have two zones:

- The first zone (0-0.6V): there is a difference between the two spectra structures that hold the layers windows i-ZnO / ZnO-Al, ITO / ZnO by Al-spectrum against both structures containing the layer windows ITO / ZnO-Al and simple structure that contains a single ZnO-Al window layer are superimposed.
- The second zone (0.6-1V): the three spectra are superimposed.

For spectral response, a significant reduction is noted for the short wavelengths between the two structures, this can be attributed to the absorption of light in the window layers and buffer layers. This explains why the incident photons of short wavelengths (blue and purple) are more sensitive to change in the nature of the layers.

Increasing the thickness of the window layer affects the density of minority carriers which are photo-generated holes. Over the region is thicker, the recombination of minority carriers is an advantage, since they must travel a greater distance to reach the junction and expelled by the field of the depletion layer to reach the p region where they become the majority

The characteristics of the semiconductor materials are strongly influenced by the impurities or the defects. The latter are added to increase the electrical conductivity or the control of the life duration, but these often these impurities or imperfections in the network from a certain

threshold act as loss factors, therefore a high concentration of defects the disadvantage transportation carriers and thus reducing the conversion efficiency.

The cell output parameters deduced from the J-V characteristics are summarized in Table 02:

Table 2. Photovoltaic parameters of the solar cell based CZTS

Paperclips Layers	**Voc(V)**	**Jsc (mA/cm^2)**	**FF(%)**	**η(%)**
CZTS/CdS/ZnO	0.8202	24.13	61.68	12.21
CZTS/CdS/ZnO/ITO	0.8201	24.03	61.67	12.15
CZTS/CdS/ZnO/i-ZnO	0.8351	19.72	61.12	10.07
CZTS/ZnSe/ZnO	0.8577	20.77	38.55	6.87
CZTS/ZnSe/ZnO/ITO	0.8406	20.73	39.31	6.85
CZTS/ZnSe/ZnO/i-ZnO	0.8739	17.23	39.85	6.00

We also note that the performance undergoes an increase in the structure ITO / ZnO / CdS / CZTS compared to the ZnO structure / i- ZnO / CdS / CZTS, and a small decrease in Jcc and FF, however, a very slight increase in Voc is noticed. The cell conversion efficiency decreases by 12.21% to 10.07%

- We also note that the yield decrease in the structure ITO / ZnO / ZnSe / CZTS over the ITO structure / ZnO / CdS / CZTS, there is a small decrease in Jcc and FF, however, a very slight increase in Voc is noticed . The cell conversion efficiency decreases by 12.15% to 6.85%.

- The first contact between the photons and the solar cell is the window layers. The increase thereof influences the creation of electron-hole pairs from photons that have an energy greater than the gap CZTS of energy is lower than that of ZnO, hence the increase performance.

4. CONCLUSION

In this work we studied the impact of CZTS-CdS layers on layers of double windows in order

to design an optimal structure which gives better electrical efficiency.

For this, we simulated the output parameters of a solar cell based CZTS to find the optimal parameters that give the best output characteristics.

We therefore studied the effect of the type of window layer i-ZnO / ZnO and ITO / ZnO on the IV characteristic as well as the electrical efficiency.

The role of antireflection layer is very important; it is used to minimize reflection losses.

The efficiency obtained for the cell that contains the ITO / ZnSe layer is of the order of 06.85%, but the cell which contains the ITO / CdS layer is of the order of 12.15%.

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How to cite this article:
Mebarkia C, Dib D, Zerfaoui H, Belghith R. Energy efficiency of a photovoltaic cell based Thin Films CZTS by SCAPS. J. Fundam. Appl. Sci., 2016, *8(2), 363-371.*

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